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ABSTRACT

Despite repeated discussions of the dangers of covariance corrections, the use of analysis of covariance (ANCOVA) continues in situations that should preclude its use. Because the use of ANCOVA is particularly appealing in much counseling research (in which groups are often intact and sample sizes are often small for treatment interventions), the purpose of this paper was to examine the use and misuse of ANCOVA in the counseling literature. The use of ANCOVA was examined in three counseling journals from 1997 through 2001. The "Journal of Counseling and Development," "Counselor Education and Supervision," and the "International Journal of Play Therapy" were selected for the study. Overall, ANCOVA was used in 21 of the 250 articles reviewed. Researchers primarily used univariate applications of ANCOVA, and generally used intact groups and unbalanced cells. Most did not comment on some basic assumptions associated with ANCOVA, including the very important homogeneity of regression assumption. Recommendations for improved use of ANCOVA are presented. (Contains 2 tables and 32 references.) (SLD)

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Current Use (and Misuse) of ANCOVA in Counseling Research

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Abstract

Despite repeated discussions of the dangers of covariance corrections, the use of analysis of covariance (ANCOVA) continues to be employed in situations that should preclude its use. Because the use of ANCOVA is particularly appealing in much counseling research (where groups are often intact and sample sizes are often small for treatment interventions), the purpose of the present paper was to examine the use (and misuse) of ANCOVA in the counseling literature. Recommendations for improved ANCOVA behavior are presented.

Current Use (and Misuse) of ANCOVA in Counseling Research

Researchers often find themselves at the mercy of intact groups (e.g., classrooms, schools, etc.) that limit, if not eliminate, the possibility of conducting true, randomized experimental research (Henson, 1998). For example, given a particular counseling intervention, it is often not possible to truly randomly assign clients to treatment and control groups. Ethical considerations also may limit the ability to deprive one group of clients from a potentially beneficial intervention. This also is a serious problem in educational circles, and accordingly, there remains a great need for experimental validation of educational programs in general (cf. Welch & Walberg, 1974).

One result of this dynamic is the tendency for researchers to either (a) use existing groups (e.g., two fifth grade classrooms) and attempt to statistically control for preexisting differences between groups or (b) use one treatment group and attempt to statistically control for preexisting variables that may impact the final outcome. These types of analyses are all related, and go by various names such as analysis of covariance (ANCOVA) and part and partial correlation.

In reviews of educational research literature analyses, ANCOVA appeared in about 4 % of the published literature (cf., Elmore & Woehlke, 1988; Goodwin & Goodwin, 1985). A more recent review indicated that ANCOVA appeared in 7% of the articles reviewed (Keselman, Huberty, Lix, Olejnik, Cribble, Donahue, Kowalchuk, Lowman, Petoskey, & Levin, 1998), suggesting the continued (perhaps increased) use of ANCOVA. In addition, Thompson (1994a) found more frequent use among doctoral students. The use of ANCOVA appears to have either remained relatively stable or slightly increased in recent years.

Like most analytic methods, it is important to realize that these corrections have certain benefits and limitations. ANCOVA, for example, is generally inappropriate when used with intact groups. And yet, ANCOVA does continue to be utilized in such situations. As Henson (1998) explained,

> Perhaps the lingering use of ANCOVA is due to the mystical promise that ANCOVA is a statistical correction of all pre-treatment problems and that it will provide increased power against Type II error. Such an argument is particularly compelling to doctoral students who find themselves aggressively seeking and even praying for statistically significant results! Unfortunately, ANCOVA has multiple assumptions that must be met before it can be accurately utilized. (p. 4)

Several researchers have documented and discussed the limitations of ANCOVA including Henson (1998), Hines and Foil (2000), and Loftin and Madison (1991). Nevertheless, the use of ANCOVA persists in situations when it is inappropriate and its assumptions have not been met.

Because the use of ANCOVA is particularly appealing in much counseling research (where groups are often intact and sample sizes are often small for treatment interventions), the purpose of the present paper was to examine the use (and misuse) of ANCOVA in the counseling literature. Three counseling journals were examined for (a) the frequency of use of ANCOVA, (b) whether important assumptions were addressed (particularly homogeneity of regression), and (c) possible misinterpretation of results stemming from misuse of the analyses. Examples of best and poor practice are offered and recommendations are presented for improved use of ANCOVA.

Important Considerations When Using ANCOVA

Researchers often confuse the concepts of methodological design and statistical analysis. These two concepts are related but separate issues in conducting quality research (Henson, 1998). ANCOVA often is used as a statistical way to equate two or more groups when the researcher is unable to randomly assign participants to treatment and control groups. Thompson (1994a) stated that some researchers appear to believe that ANCOVA magically corrects for pre-existing group differences. Researchers often use ANCOVA as a way of dealing with methodological design flaws (Henson, 1998), albeit unavoidable flaws in many instances.

Loftin and Madison (1991) stated that ANCOVA received favorable treatment in Campbell and Stanley (1963), which may have influenced researchers to regard ANCOVA as a panacea for many research problems. Later, Campbell and Erlebacher (1975) clarified statements made in the previous publication. Campbell and Erlebacher argued that ANCOVA is rarely useful because the more a researcher needs the controls of ANCOVA, the more biased the outcomes of the analysis. Unfortunately, many researchers cite the earlier Campbell publication and fail to mention the latter one.

In fact, a methodological design is either experimental or not (Henson, 1998). In nonexperimental studies where random assignment is not used, the use of a statistical tool such as ANCOVA does not transform the study into an experimental one. When participants are not randomly assigned to groups, ANCOVA often is not being used as originally intended. Researchers who use existing groups in their studies know that their studies are at a greater risk for sampling error. If a researcher conducts a study that also

has a small sample size, the risk obviously increases (Huck, 2000). Unfortunately, ANCOVA does not dissolve the sampling present in a study.

Importantly, ANCOVA only accurately adjusts for pretreatment group differences when important methodological assumptions are met (Huck, 2000; Thompson, 1994a). These data assumptions include the homogeneity of regression, homoscedasticity, homogeneity of variance (after the covariate is removed), and normality of the dependent variable. Violating these assumptions can affect the Type I error rate (Keselman, et al., 1998). A more thorough summary and discussion of these assumptions can be found in Loftin and Madison (1991) and in Shavelson (1996).

What ANCOVA Is

According to Henson (1998), ANCOVA is a "regression of a covariate variable on the dependent variable from the entire sample ignoring group membership, at least if ANCOVA assumptions are perfectly met" (p. 7). Thompson (1994a) stated that ANCOVA residualizes the "dependent variable of all the variance that is linearly predictable with the covariate variable(s). Then the resulting 'error' or 'e' scores are used as the new dependent variable in an ANOVA" (p. 25). The intent of ANCOVA is to "assign a portion of the variance in the dependent variable that would normally be attributed to error in a regular analysis of variance (ANOVA) to an extraneous covariate variable" (Henson, 1998, p. 7).

When applied appropriately, ANCOVA can provide increased power against Type II error. However, the methodological assumptions that are required to be met when using ANCOVA are rarely satisfied (Henson, 1998; Loftin & Madison, 1991). ANCOVA's promise of increased power against Type II error is only fulfilled in cases in

which the covariate is uncorrelated with the independent variable. In fact, the covariate may rob the independent variable of some the variance attributed to it if the two variables are correlated (Henson, 1998). As Thompson (1994a) stated:

> When the covariate is related to the treatment variable, use of the covariance correction will alter the effects attributed to the treatment itself. For example, one might have a very effective intervention that looks completely ineffectual, because the covariate is given credit for the variance that would correctly otherwise be attributed to the treatment variable. (p. 27)

Thus, the use of the ANCOVA correction may actually decrease power against Type II error if the covariate robs the treatment variable of its effect. Of course, researchers can verify the magnitude of the relationship between the covariate and the grouping variables by finding the correlation between them. If these variables are correlated, the effects attributed to the treatment effect could be altered.

Although it is seldom examined, an easy to evaluate the relationships between the covariate and dependent variable and the covariate and the grouping variable would be to simply calculate the Pearson r between the variables or examine some index of effect size (e.g., perhaps use η^2 for the effect between a continuous covariate and categorical grouping variable). This would help researchers to evaluate whether the ANCOVA might actually reduce power against Type II error.

Some Important (Often Overlooked) Assumptions Related to ANCOVA

As previously stated, several methodological assumptions must be met in order for ANCOVA to be used accurately. As demonstrated by Henson (1998), ANCOVA is essentially a two-stage analysis. In the first stage, the dependent variable is regresses on

the covariate (s) ignoring group membership as one would in a traditional regression analysis. Therefore, all of the assumptions related to regression, such as homoscedasticity, would be applicable for this stage of the analysis.

In the second stage, a traditional ANOVA is performed on the residualized dependent variable (i.e., the error scores that were not predictable by the covariate). Therefore, all the assumptions of a traditional ANOVA would apply here, including homogeneity of variance between groups and normalcy of the dependent variable (particularly when sample sizes are small) (Huck, 2000).

These expectations notwithstanding, ANCOVA has an additional assumption that serves as a bridge of sorts between the two stages. This assumption is called homogeneity of regression and will be discussed briefly here. Thompson (1994a, p. 28) noted that statisticians use the name homogeneity of regression assumption because the phrase sounds fancier than the "equality of the B weights" assumption. If the groups used in ANCOVA were not created through random assignment (which is often the case), the B weight relationships between the covariate and the dependent variable often are not equivalent across the groups.

The goal of ANCOVA is to equate groups on some variable before analyzing the treatment effects. When the regression of the covariate on the dependent variable is performed, group membership is ignored. If one regression equation is used for all groups (as it is in ANCOVA), the equation must be representative of each of the groups examined individually, otherwise the use of the single equation will distort the residualized dependent variable scores (Henson, 1998). Intuitively, we know that if the

regression slopes are notably different in the individual groups, the pooled regression slope does not accurately represent any of the groups.

If researchers do not examine the slopes of the individual groups in order to determine if they are (roughly) the same, these researchers risk applying ANCOVA to unequivalent groups and not representing any group well (Loftin & Madison, 1991). Loftin and Madison stated that the homogeneity of regression assumption "requires that the relationship between the dependent variable Y and the covariate X is constant within all k levels of the independent variable (K)" (p. 141). Because of its importance, Huck (2000) noted, the homogeneity of regression assumption "should always be tested when ANCOVA is used" (p. 552, emphasis in original).

Method

Article Selection

In the current study, we examined the use of ANCOVA in three counseling journals from 1997-2001. All articles appearing in the *Journal of Counseling and Development* (*JCD*), *Counselor Education and Supervision* (*CES*), and the *International Journal of Play Therapy* (*IJPT*) were selected for this study. *JCD* is the official journal of the American Counseling Association with a circulation of over 50,000. *CES* and *IJPT* are specialty journals with greater focus on counselor education and practice. Book reviews, practice-based articles, and editorial addresses were deleted.

Articles were coded into categories as reflected in Table 1. In previous studies, ANCOVA was used in 4-7% of the articles reviewed (cf. Elmore & Woehlke, 1988; Goodwin & Goodwin, 1985; Keselman et al., 1998). In the current study, we found that

ANCOVA was used in 21 studies, which was 8% of the 250 articles reviewed. As Table 1 indicates, ANCOVA was more popular in the *JCD* and *IJPT* than it was in *CES*.

INSERT TABLE 1 ABOUT HERE

The variables that we utilized in analyzing the ANCOVA's are presented in Table 2. We included every application utilized in the ANCOVA articles; therefore, the number of applications of ANCOVA reflects higher frequencies than the total number of ANCOVA articles. Several researchers conducted multivariate and univariate applications in the same study. We examined each application of ANCOVA to see how researchers addressed (a) design characteristics, (b) assignment of participants to groups, (c) the selection of covariate(s), (d) assumptions, and (e) use of effect sizes to describe relationships between the covariate and the dependent variable, covariate and the grouping variable, and main/interaction effects.

INSERT TABLE 2 ABOUT HERE

Design

As Table 2 indicates, researchers used one-way designs in the vast majority (87%) of their applications of ANCOVA and MANCOVA. Univariate uses (94%) were much more popular than multivariate (6%). In all five uses of MANCOVA, the multivariate analysis was followed post hoc with a univariate test. Although it is beyond the scope of this paper to discuss the issue fully, it is inconsistent to first declare interest in a multivariate system of variables then use univariate tests to evaluate the contributions of the dependent variables (cf. Fish, 1988; Henson, 1999; Thompson, 1994b). A better

procedure would be to follow factorial MANCOVA with another multivariate procedure such as discriminant analysis (Huberty, 1994).

Researchers also used unbalanced designs (86%) much more than they used balanced designs. This finding was higher than the percentage of unbalanced designs (75%) found by Keselman et al. (1998). In the current study, however, some of the studies used cells that were close to balanced. Ray and Altekruse (2000), for example, used a one-way design with three levels. The cell sizes were 22, 20, and 22. On the other hand, the cells of Ægisdottir and Gerstein (2000) in their three-way design were very unbalanced. Their cells were nationality (261, 225), gender (150, 334), and personality type (299, 66, 30). As Keselman et al. (1998) have stated, when group sizes are unequal, the effects of validity assumption violations can be exacerbated. In some studies, basic descriptive statistics and cell sizes were not even given. In Crutchfield and Borders (1997), the researchers included information about the three groups of supervisees, but did not include information about cell sizes for client groups and gender groups.

As stated previously, many researchers have cited Campbell and Stanley (1963) as a rationale for utilizing a "quasiexperimental", nonequivalent group design. For example, Harris and Landreth (1997) stated that, "a pretest-posttest, nonequivalent control group design (Campbell & Stanley, 1963) was used in this study ..." (p. 61). As Loftin and Madison (1991) mentioned, however, Campbell and Erlebacher (1975) clarified the limitations of ANCOVA that were not specifically addressed in the earlier publication.

Unfortunately, most of the ANCOVA applications that we examined were used with intact groups (86%). By contrast, Keselman et al. (1998) found that 67% of the

ANCOVA studies they reviewed used nonrandomized experimental units. As Henson (1998) and Loftin and Madison (1991) have cautioned, using ANCOVA with intact groups is problematic. ANCOVA does not correct for all of the pre-treatment differences that researchers often believe it does. In some of the studies that we examined group assignment was ambiguous. In Chau and Landreth (1997), the researchers stated that participants "were assigned to a control group or an experimental group according to their work or school schedule" (p. 78). In the next paragraph, Chau and Landreth reported that participants were "randomly selected into the experimental group" (p. 79).

Assumptions

As Table 2 indicates, researchers only verified the homogeneity of regression assumption in 17 of the 86 applications (20%). This percentage is similar to Keselman et al. (1998), where 18% of the studies utilizing ANCOVA commented on the homogeneity of regression assumption. All of the researchers in the current study who verified the homogeneity of regression assumption utilized statistical significance testing to determine whether the slopes were parallel (equal). For example, Sullivan and Mahalik (2000) stated that, "tests for regression parallelism were calculated. Results for these tests indicated that there were no significant age by condition interaction effects on the pre- and posttest CDMSE and VEC scores" (p.59). One limitation of using this approach to check the equality of the slopes is that statistical significance testing is heavily impacted by sample size (Cohen, 1994; Daniel, 1998; Henson & Smith, 2000; Thompson, 1996; Thompson & Snyder, 1998).

For example, gross slope differences could be overlooked with small sample sizes because the differences may not be statistically significant. With large sample sizes,

trivial differences in slope could yield statistically significant results even though the differences in slope are not practically different. Because many of the articles examined in the current study had very small sample sizes, it is possible that even if a researcher verified the homogeneity of regression assumption with a statistical significance test, the researcher could still be dealing with notable differences in the slopes. This unintentional omission could distort the results of the ANCOVA.

Loftin and Madison (1991) recommended examining the homogeneity of regression by using a scatterplot of the association instead of a test of statistical significance. A scatterplot allows the researcher to visually inspect whether the slopes are reasonably parallel across all of the groups and is consistent with calls for increased graphical examination of our data (Wilkinson & APA Task Force on Statistical Inference, 1999).

As Table 2 indicates, none of the other validity assumptions that we examined were verified. Specifically, researchers in this study did not verify the assumptions of normality and homogeneity of variance, which also were given little attention in the Keselman et al. (1998) review of ANCOVA. These authors found that only 4% of the ANCOVA articles that they examined considered the assumption of normality and only 9% of the studies examined commented on homogeneity of variance.

Relationships Between Study Variables: Effect Sizes

Authors reported any kind of effect size in the current study in only 3 of 86 (4%) of the applications of ANCOVA. The only effect sizes that were reported were for main treatment effects or interaction effects, and all were standardized mean differences. In only one case did the researcher also interpret the magnitude of the effect size.

The lack of effect reporting in these articles is not consistent with current methodological trends (Daniel, 1998; Thompson, 1996; Thompson & Snyder, 1998). Indeed, the fifth edition of the American Psychological Association Publication Manual (2001) called the "failure to report effect sizes" a "defect in the design and reporting of research" (p. 5). The *Manual* later observed: "For the reader to fully understand the importance of your findings, it is almost always necessary to include some index of effect size or strength of relationship in your Results section" (p. 25). Fortunately, some journals such as JCD now require effect reporting. Readers are referred to a recent JCD article (Thompson, in press) for more information regarding various kinds of effects and result significance.

In some cases, the reporting of effect sizes would have provided greater clarity on the "practical" significance of authors' findings. In Crutchfield and Borders (1997), for example, the researchers stated that, "these individually nonsignificant results showed movement in the preferred direction each time, indicating small but pervasive effects of treatment" (p. 226). Reporting of effect sizes would have allowed evaluation of the magnitude of these effects. Similarly, Tyndall-Lind, Landreth, and Giordano (2001) stated, "the results from this study strongly point to the effectiveness of intensive sibling group therapy in a variety of areas with child witnesses of domestic violence" (p. 67). Effect sizes could have quantified how "strongly" the treatment impacted the children in the study.

Important for ANCOVA use are the relationships between the covariate and the dependent and grouping variables. As Table 2 indicates, none of the researchers reported the correlations between the covariates and the grouping variables. This finding was

unfortunately expected, of course, and comparable to Keselman et al. (1998), who stated that the researchers that they reviewed "generally ignored the interaction effects between the covariate(s) and the grouping variables" (p. 376). This effect size relationship is important because if the grouping variables are correlated with the covariate, the initial regression of the covariate can remove parts of the sum of squares explained by the grouping variables (Loftin & Madison, 1991). Therefore, the researchers in the current study were seemingly unaware of how much their covariates may have robbed the effect attributed to their treatment variables.

Further, the relationship between the covariate and the dependent variable was never reported. Because the covariate removes variance from the dependent variable, the magnitude of this relationship is critical to understanding the remaining residualized variable. In cases when the covariate has a strong relationship with the dependent variable, Henson (1998) suggested that, "one must question what is left of the...dependent variable after the dramatic impact of the covariate" (p. 15). As Thompson (1992) explained, "Statistical corrections remove parts of the dependent variable and then analyze whatever's left, even if whatever's left no longer makes any sense. At some point, we may no longer know what it is we're analyzing" (pp. xiii-xiv). Given that (a) 85% of the covariates used were simply pre-test versions of the dependent variable and (b) that we might hope for reasonable test-retest reliability between pre- and post-testing (e.g., moderate to strong relationships between the covariate and dependent variable scores), it is not unreasonable to suspect that in many cases the studies examined here analyzed a residualized dependent variable that may not have possessed the same degree of validity as the original scores.

Summary and Recommendations

Our examination of the 21 articles that reported 86 applications of ANCOVA revealed that these counseling researchers primarily used univariate applications of ANCOVA. The researchers generally used intact groups and unbalanced cells in most of their studies. In addition, most did not comment on some basic assumptions associated with ANCOVA including the very important homogeneity of regression assumption. Keselman et al.'s (1998, p. 376) claim that, "researchers appear to be unaware of, or at least fail to recognize, the assumptions that underlie the statistical models that they use" appears applicable to the current selection of ANCOVA articles.

We also found that effect sizes were ignored by most of the researchers reviewed. The relationship between the covariate (s) and the grouping variable (s) was completely overlooked, as was the relationship between the covariate (s) and the dependent variable (s).

Based on our review of the use (and misuse) of ANCOVA in the counseling literature examined here, we recommend the following:

1. Verify the homogeneity of regression assumption. As Huck (2000) stated, the homogeneity of regression assumption needs to be verified in every use of ANCOVA. ANCOVA cannot be used appropriately unless regression slopes are parallel (Loftin & Madison, 1991).
2. Utilize scatterplots to verify the homogeneity of regression assumption. If researchers use statistical significance tests to examine this assumption, they can misinterpret the results if the sample size is small or large (Loftin & Madison, 1991). Scatterplots allow the researchers to visually inspect the regression slopes.

3. Report treatment and interaction effect sizes. In this study, effect sizes were rarely reported. Effects allow researchers to evaluate more clearly (and communicate to the reader) the practical significance of their results.
4. Examine and report the correlation between the covariate (s) and the grouping variable (s). If the covariate and the grouping variables are correlated, the covariance correction may alter the effects attributed to the treatment.
5. Examine and report the correlation between the covariate (s) and the dependent variable (s). The magnitude of this relationship helps with the interpretation of the residualized dependent variable.
6. Utilize reasonably balanced cell designs with ANCOVA. Utilizing excessively disproportionate group sizes may raise concern about the statistical validity of one's findings (Keselman et al., 1998).

Henson (1998) noted that, "As with most statistical analyses, ANCOVA can be reasonably applied when its assumptions have been met" (p. 15). However, it is problematic that, generally, ANCOVA is most desired as a statistical correction when the study features most preclude its use, such as when using unequal, intact groups. At a minimum, authors are encouraged to apply ANCOVA with caution. These recommendations may be useful in helping counseling researchers thoughtfully employ this method.

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Table 1

Types of Articles Reviewed Including ANCOVA

Type of article	Journal *JCD*	*CES*	*IJPT*	Total
Descriptive	7	13	4	24
Inferential(ANCOVA)	68(9)	27(2)	19(10)	114
Qualitative/theory	63	32	17	112
Total articles reviewed[a]	138	72	40	250

[a] Articles that were practice-based were excluded.

Table 2

Summary of ANCOVA Applications (n=86)[b]

Design	*n*	Grouping	*n*	Covariates	*n*
One Factor	75	Intact	74	Nature:	
Two Factor	1	Matching	4	Pre-test	73
Three factor	10	Random Assignment	8	External	13
Univariate	81				
Multivariate	5				
MANCOVA/ANCOVA post hoc	4			Number:	
MANCOVA/ANOVA post hoc	1			Single	85
Balanced	12			Multiple	1
Unbalanced	74				

Assumptions/Effect Sizes

Assumptions	*n*	Effect Sizes/Relationships	*n*
No comment	69	No comment on effect	83
Homogeneity of reg.	17	Correlation b/t Covariate/DV	0
Homoscedasticity Cov/DV	0	Correlation b/t Cov/Group Var.	0
Homogeneity of variance	0	Main effect/interaction effect	3
Normality	0		

[b] Totals are greater than the number of articles because the total number of ANCOVA applications were examined.

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